

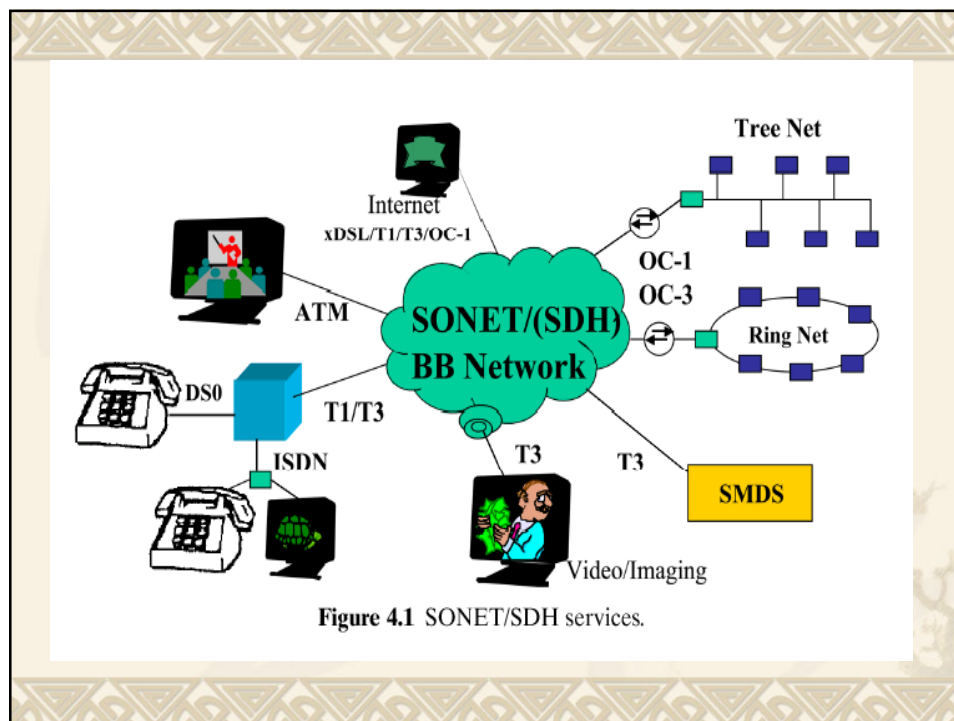
SONET/SDH : Introduction

- ❖ The evolution of the optical fiber to a high-speed, low-cost transmission medium led to the Synchronous Optical Network (SONET) standard in the United States and the Synchronous Digital Hierarchy (SDH) in Europe.
- ❖ Fiber had already been proven as a transmission medium in precursor fiber systems .
- ❖ Since 1980s, SONET and SDH have almost replaced all **long-haul copper cable** and thousands of miles of new fiber are being in-stalled each year.
- ❖ The optical fiber has responded to an unexpected increase in traffic demand and the much-touted "superhighway" is history in the making.

WHAT ARE SONET AND SDH?

- ❖ SONET is a set of standard interfaces in an optical synchronous network of elements (NE) that conform to these interfaces.
- ❖ SONET interfaces define all layers, from the physical to the application layer.
- ❖ SONET is a **synchronous network**.
- ❖ SDH is also a synchronous network with optical interfaces.
- ❖ SDH is a set of standard interfaces in a network of elements that conform to these interfaces.
- ❖ Like SONET SDH interfaces define all layers, from the physical to the application layer.
- ❖ It seems that SONET and SDH are identical.

- ❖ systems and networks are being developed that can transport any type of traffic.
- ❖ Voice, video data, Internet, and data from LANs, MANS (Metropolitan Area Network), and WANs will be transported over a SONET or a SDH Network.
- ❖ The SONET network is also able to transport asynchronous transfer mode (ATM) payloads.
- ❖ These systems, called **broadband**, can manage a very large aggregate bandwidth or traffic.



Similarities between SONET/SDH

- ❖ Bit rates and frame format organization
- ❖ Frame synchronization schemes
- ❖ Multiplexing and de-multiplexing rules
- ❖ Error control

Differences

- ❖ The definition of overhead bytes is very similar, but some variations have been introduced to accommodate differences between U.S. and European communications nodes and networks.
- ❖ The SDH photonic interface specifies more parameters than SONET.
- ❖ SONET and SDH standards have enough minor technical and linguistic differences (i.e., terminology) to add complexity (and cost) in their design [hardware, software (HW, SW)].

SONET and SDH advantages

- ❖ Therefore, networks and systems that offer low cost per bit per kilometer are very critical in communications.
- ❖ **SONET and SDH advantages**
 - ☞ **Reduced cost:** a. It lowers operations cost. b. It has the same interface for all vendors.
 - ☞ **Integrated network elements:** a. It allows for multivendor internetworking. b. It has enhanced network element management.
 - ☞ **Remote operations capabilities:** It is remotely provisioned, tested, in-ventoried, customized, and reconfigured.
 - ☞ It offers **network survivability features**.
 - ☞ It is compatible with **legacy and future networks**.

Rates

- ❖ SONET and SDH rates are defined in the range of **51.85-9953.28 Mbps** (almost 10 Gbps) and higher rates, at 40 Gbps, are also under study.
- ❖ When the SONET signal is in its electrical nature, it is known as **synchronous transport signal level N (STS-N)**.
- ❖ The SDH equivalent is called **synchronous transport module level N (STM-N)**. After its conversion into optical pulses, it is known as optical carrier level N (**OC-N**).

Rates

| Signal Designation | | | Line Rate (Mbps) |
|--------------------|--------|-----------|---------------------|
| SONET | SDH | Optical | |
| STS-1 | STM-0 | OC-1 | 51.84 |
| STS-3 | STM-1 | OC-3 | 155.52 |
| STS-12 | STM-4 | OC-12 | 622.08 |
| STS-48 | STM-16 | OC-18 | 2,488.32 |
| STS-192 | STM-64 | OC-192 | 9,953.28 |
| | | OC-768(?) | 39,813.12 |

WHY USE SONET/SDH?

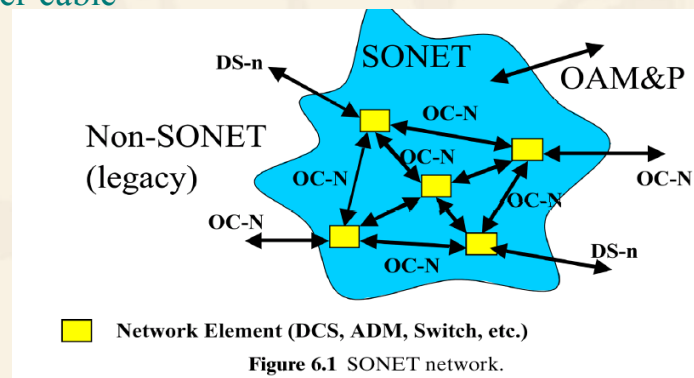
- ❖ The basic differentiator between SONET/SDH and traditional (copper) networks is the transmission medium, the glass fiber versus the copper wire.
- ❖ “Why is glass fiber better than copper wire?”
 - ⌚ **Higher transmission reliability:** Glass fiber is not as susceptible to radio frequency or electromagnetic interference (RFI, EMI) as copper wire unless it is shielded and well grounded.
 - ⌚ **Lower bit error rate (BER).** Unlike electrical signals in copper cables, light signals transmitted along a bundle of fibers do not interact. This results in lower inter-symbol errors and thus fewer transmission errors.

Why SONET/SDH? (cont.)

- ❧ **Higher bandwidth per fiber:** A single strand of glass fiber can pass more than 1,000,000 times information than copper wire can. This enables very high capacity systems at lower cost per megabytes per second.
- ❧ **Fiber can transmit without repeaters at longer distances as compared with copper:** This simplifies maintenance and lowers operation cost (per megabytes per second).
- ❧ **Fiber yields thinner cable** (per megahertz or gigahertz bandwidth) than copper.
- ❧ **SONET/SDH is based on standards,** which enables multivendor compatibility and interoperability.

SONET/SDH

- ❖ The SONET/SDH network consists of nodes or network elements (NEs) that are interconnected with fiber cable



SONET/SDH

- ❖ SONET NEs may receive signals from a variety of facilities such as DS1, DS3, ATM, Internet, and LAN/MAN/WAN.
- ❖ They also may receive signals from a variety of network topologies such as rings or trees, for example a LAN at 10 Mbps, 100 Mbps, or higher bit rates.
- ❖ However, SONET NEs must have a proper interface to convert (or emulate) the incoming data format into the SONET format.
- ❖ SONET<->SDH

Network topology

- ❖ In general, networks fall into three topologies: tree, ring, and mesh .
- ❖ SONET/SDH networks are based on the ring topology.

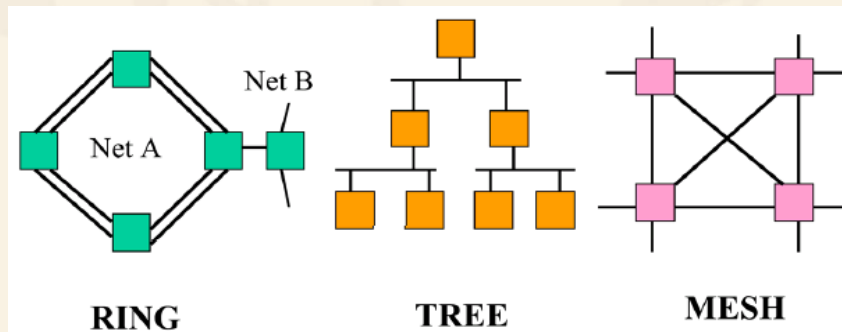


Figure 6.2 Ring, tree, and mesh topologies.

SONET Hierarchical

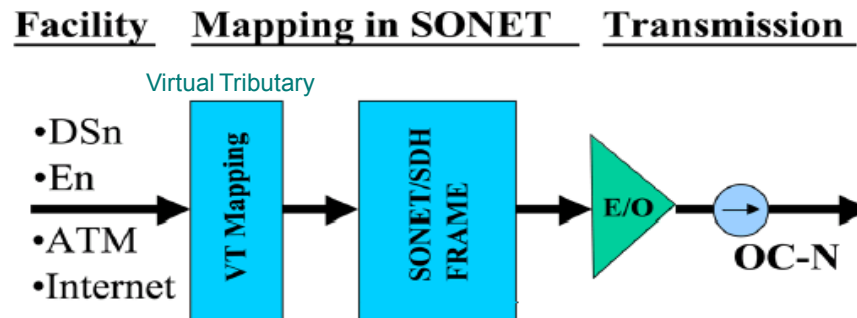
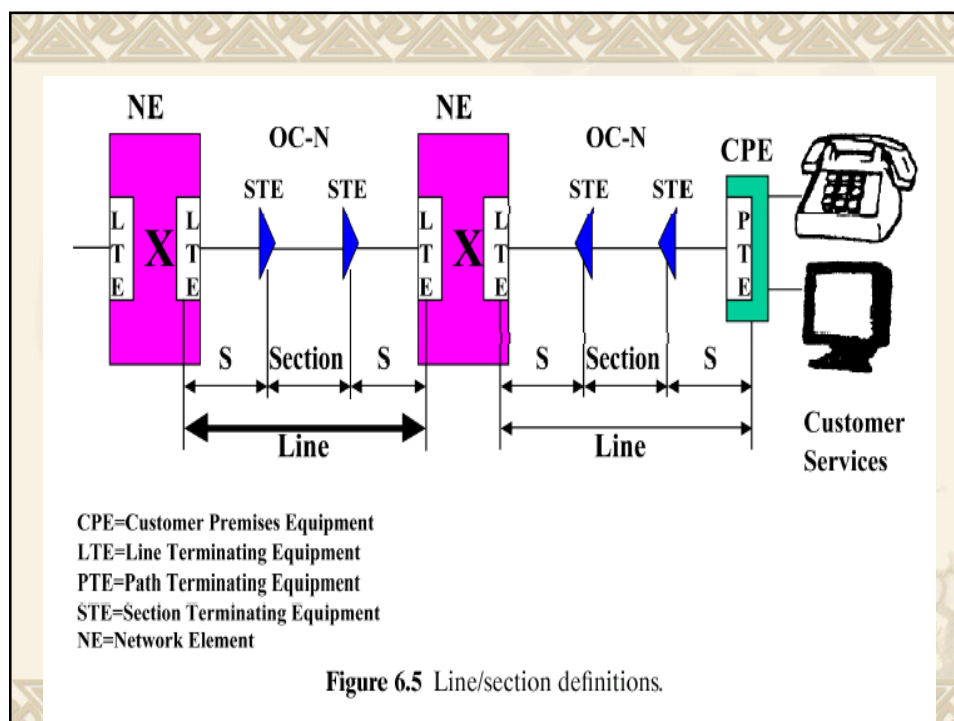
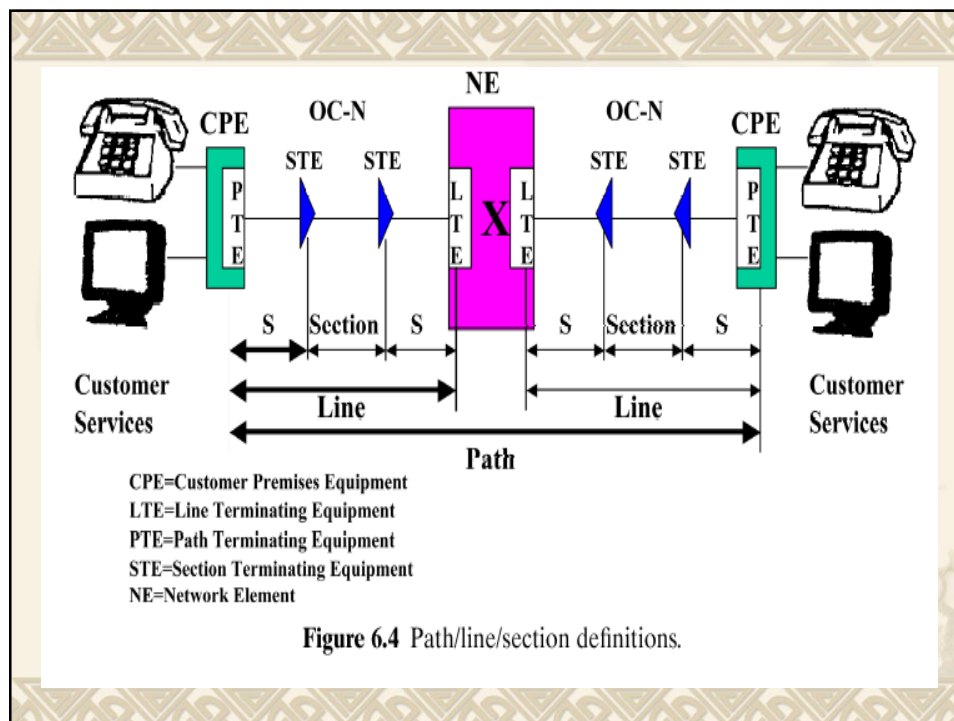
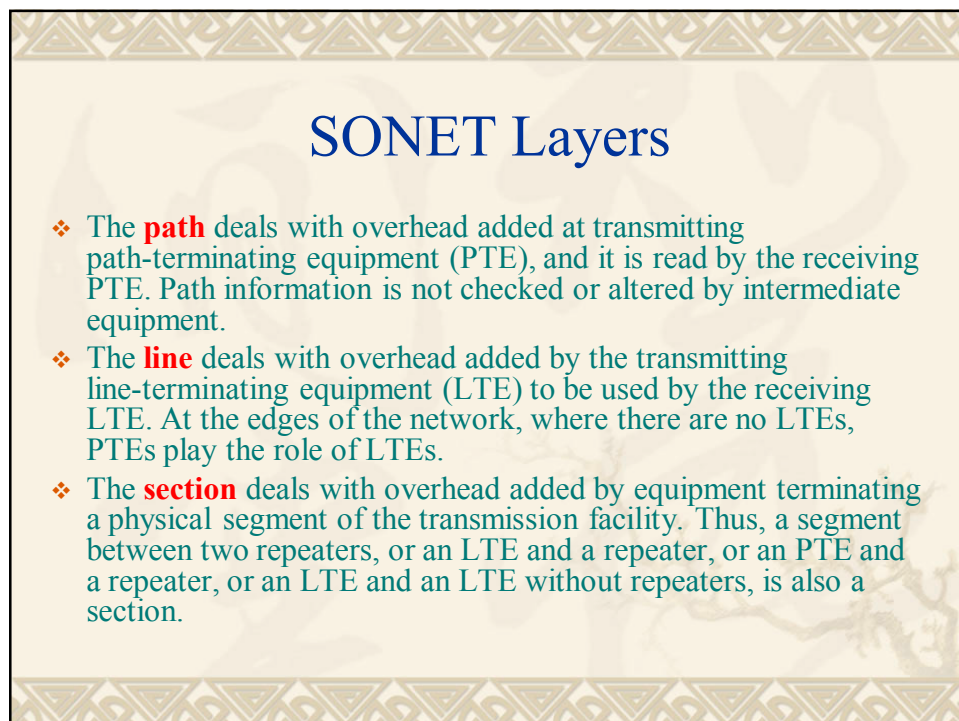
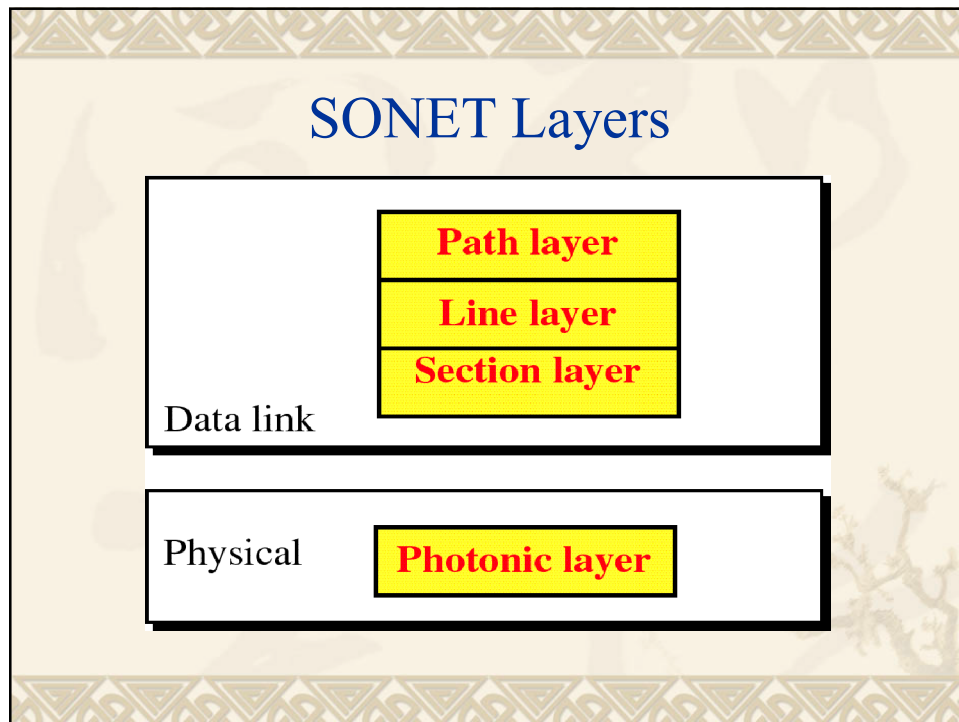


Figure 6.3 SONET hierarchy.

- ❖ A SONET/SDH frame is transmitted from an end user through one or more nodes in the network to eventually reach another end user.
- ❖ As information moves from node to node, certain operations take place to assure the deliver-ability and integrity of the signal.
- ❖ This means that additional information (bits), or overhead bits, must be added to the sending signal to be used for net-work administration purposes.
- ❖ This is equivalent to a letter that has an address on it, and is packed in a post office bag on which additional information (a la-bel) is added; this bag may also be enclosed in a larger container with more labels on it.
- ❖ This overhead information is transparent to the end user; that is, it is not delivered as the tags are not delivered with the letter. In addition, the overhead has been organized hierarchically in the following administrative sectional responsibilities (Figure 6.4):

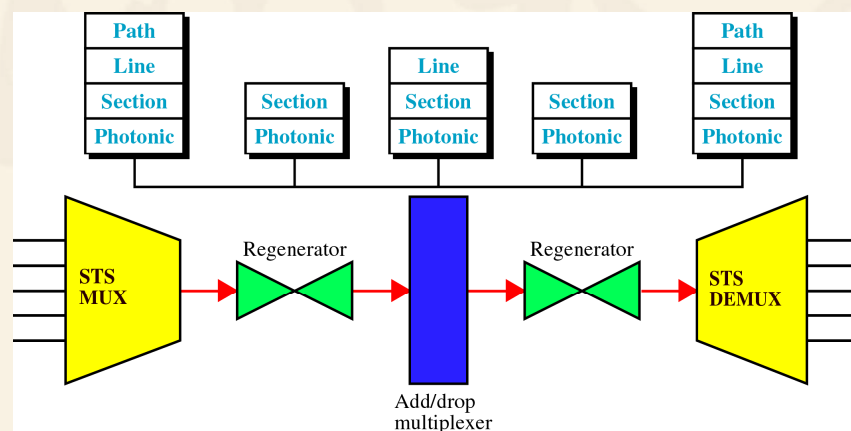




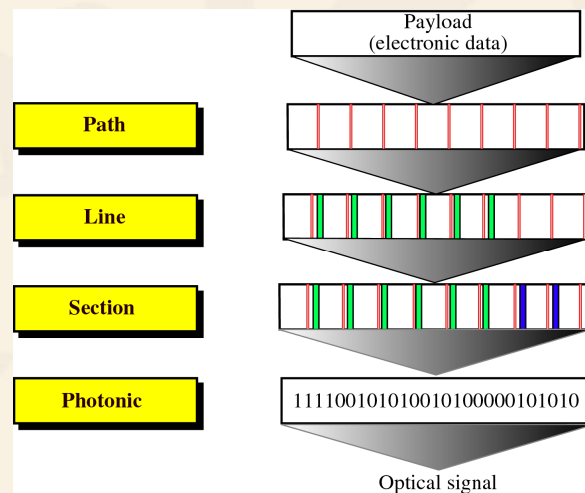
SONET Layers

- ❖ Photonic layer
 - ☞ Physical layer of the OSI model
- ❖ Section layer
 - ☞ Movement of a signal across a section
 - ☞ Framing, Scrambling, Error monitoring
- ❖ Line layer
 - ☞ Movement of a signal between two multiplexers
 - ☞ Synchronization, Multiplexing
- ❖ Path layer
 - ☞ Movement of a signal between two STS multiplexers
 - ☞ End-to-end data transport

Device-Layer Relationship



Data Encapsulation in SONET



STS-1

- ❖ SONET frame is a two-dimensional matrix of 9-row-by-90-column bytes. In SONET, this is known as an STS-1 frame.
- ❖ The first 3 columns of the STS-1 frame contain the **transport overhead**, which is overhead pertaining to section and line.
- ❖ The byte capacity contained from the fourth column (included) to the last is called a **synchronous payload envelope (SPE)**.
- ❖ The fourth column of the STS-1 frame (or the first of the SPE) contains **path overhead** information.
- ❖ Two columns in the SPE (columns 30 and 59 of the STS-1), known as **fixed stuff**, do not contain any information.
- ❖ The actual payload capacity is obtained from the space SPE by subtracting 3 columns, the path and the two fixed-stuff columns. That is, a total of 84 columns (or 756 bytes) are used for payload, or 48.384 Mbps effective bit rate.

STS-1

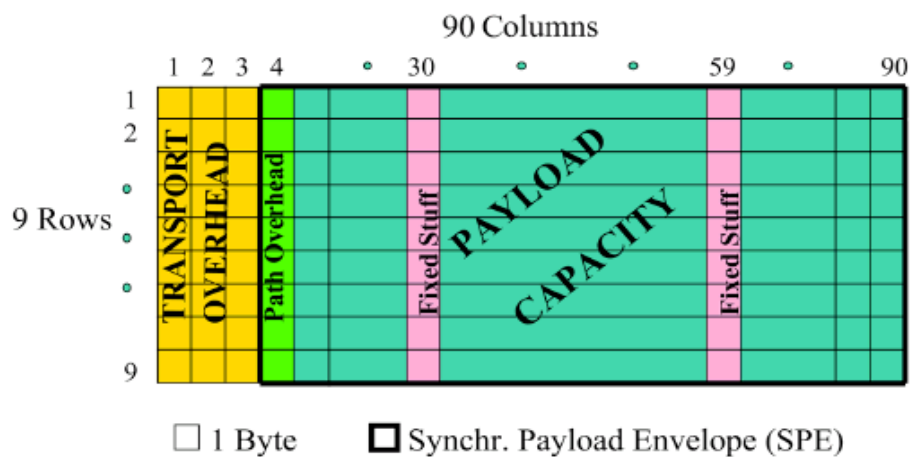
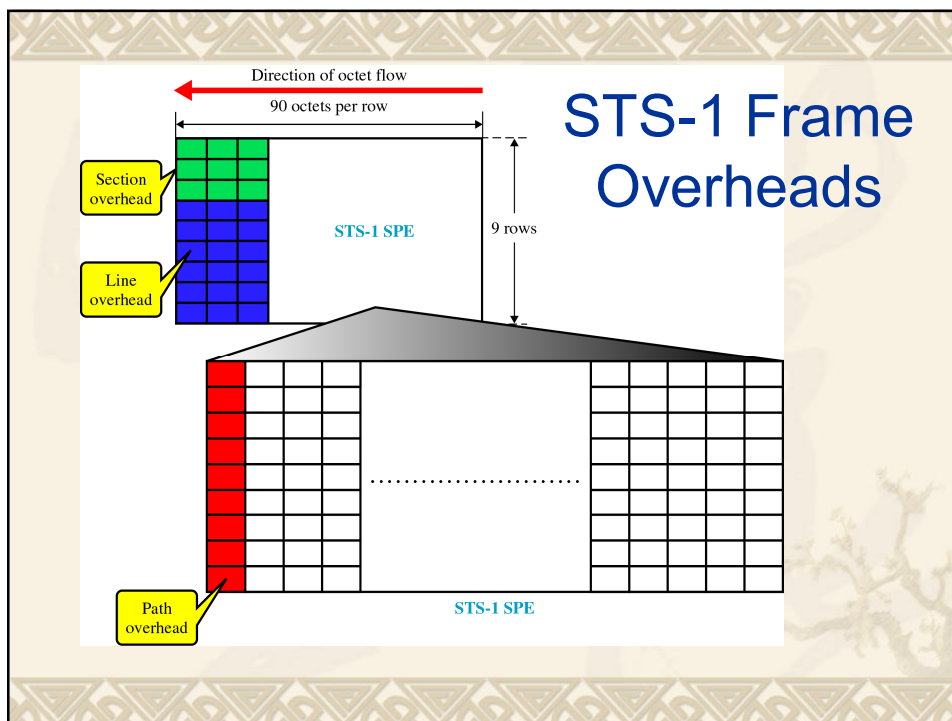


Figure 7.1 SONET STS-1 frame structure.

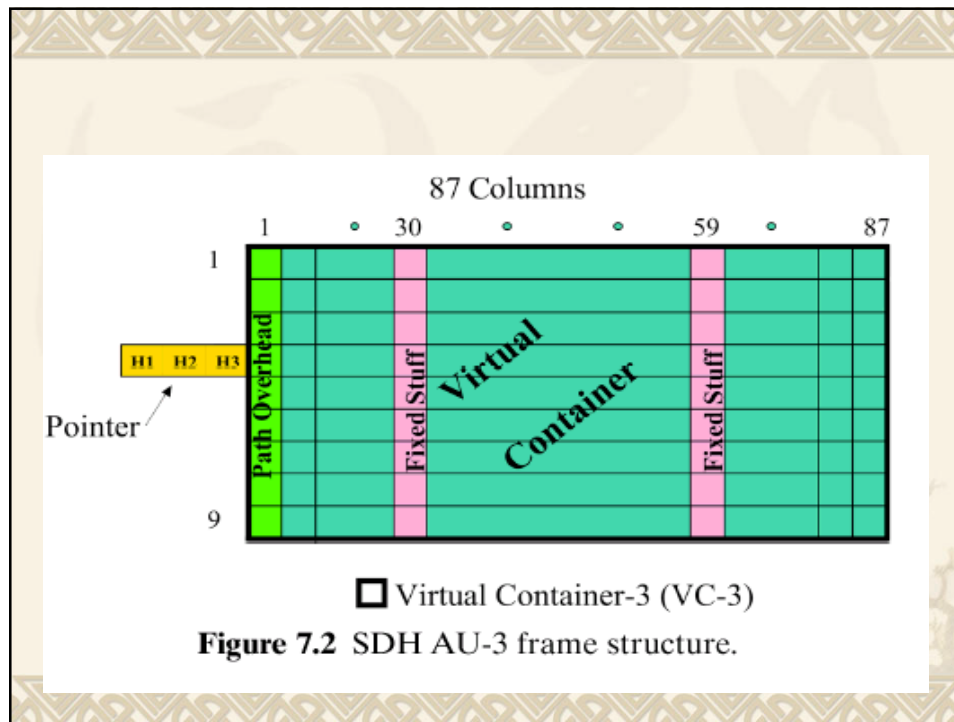


STS-1

- ❖ The SPE consists of 87 columns and 9 rows, or 783 bytes.
- ❖ The first column (9 bytes) of the SPE is allocated for the STS path over-head.
- ❖ Columns 30 and 59, known as fixed stuff, do not contain any actual pay-load. The 756 bytes in the 84 columns are designated as the STS-1 pay-load capacity.

SDH AU-3

- ❖ SDH does not specify a frame similar to SONET STS-1.
- ❖ However, it specifies a payload container as small as the SONET SPE.
- ❖ The smallest SDH payload container is visualized as a two-dimensional matrix of 9 rows by 87 columns. This is known as virtual container 3 (VC-3).
- ❖ The VC-3 also contains a column for path overhead, called the VC-3 path overhead (VC-3 POH), and two fixed-stuff columns.
- ❖ Thus, the actual payload capacity in a VC-3 is 84 columns (or 756 bytes), similar to the SONET case.



AU-3

- ❖ At the VC-3 and in the fourth row, three additional bytes are added for the VC-3 pointer (H1, H2, and H3). The end result, VC-3 and the pointer, comprises the **administrative unit level 3 (AU-3)**. When three such AU-3's are byte multiplexed, the end result will be the **administrative unit group (AUG)**.

TRANSMITTING AN STS-1

- ❖ Consider that an STS-1 frame needs to be transmitted one bit at a time over a transmitting (optical) facility. The question is: How is this done?

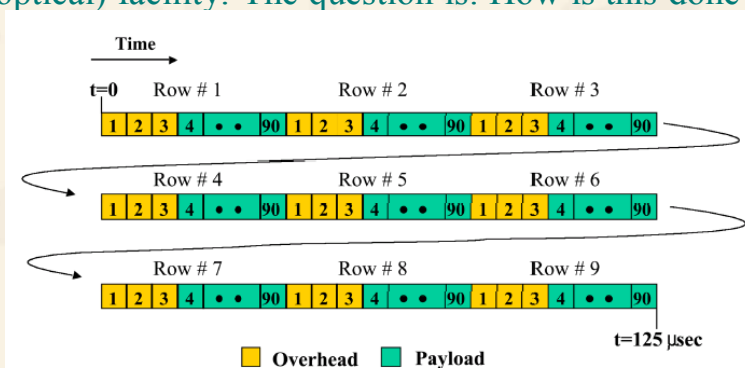


Figure 7.3 SONET STS-1 frame: unfolded.

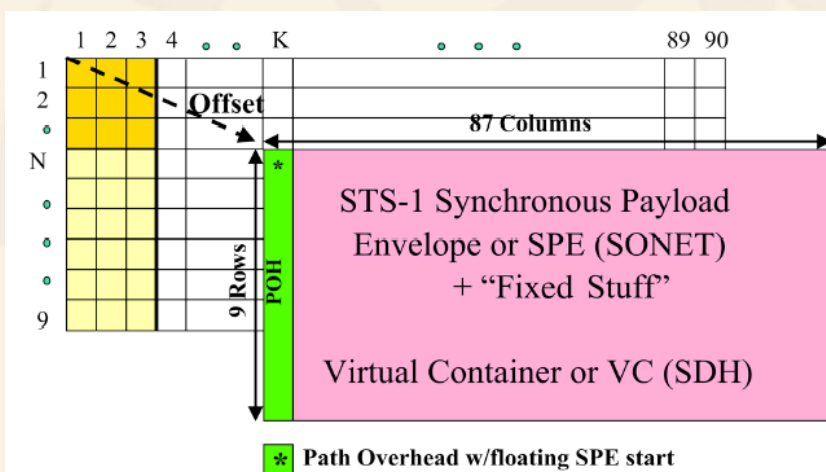
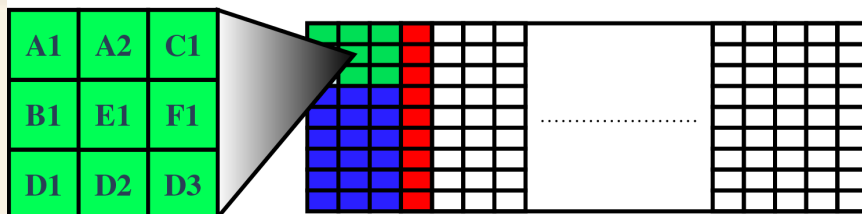


Figure 7.6 SONET STS-1 with floating SPE.

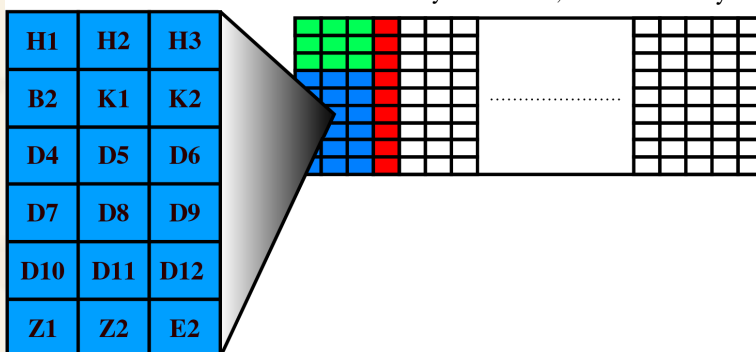
STS-1 Frame: Section Overhead

A1: Alignment 1 A2: Alignment 2 C1: Identification
 B1: Parity byte E1: Orderwire byte F1: User
 D1: Management D2: Management D3: Management

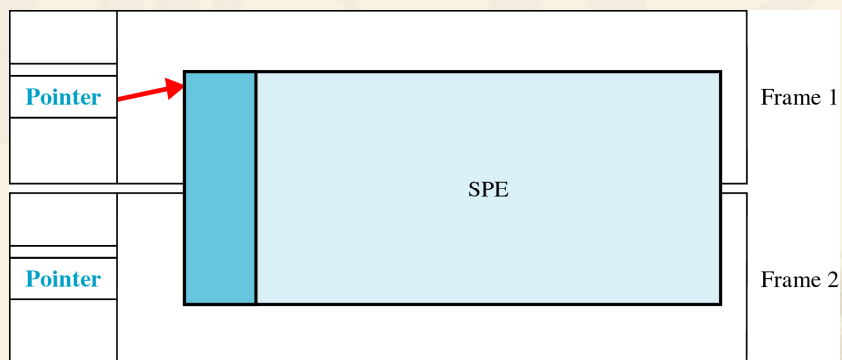


STS-1 Frame: Line Overhead

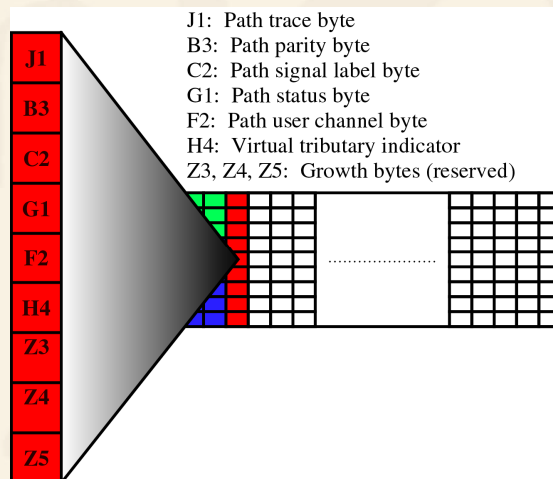
H1, H2, H3: Pointers B2: Line parity byte
 K1, K2: Automatic protection switching bytes E2: Orderwire byte
 D4-D12: Data communication channel bytes Z1, Z2: Growth bytes



Payload Pointers



STS-1 Frame: Path Overhead



STS Multiplexing

